ELECTRICAL PLANS AND SPECIFICATIONS FOR A PHYSICAL TRAINING CENTER

Mc K

A THESIS

Submitted in partial fulfillment
of the requirements for the Degree
of Electrical Engineer

by

Howard L. McKinley

Georgia School of Technology
Atlanta, Georgia
1946

ELECTRICAL PLANS AND SPECIFICATIONS
FOR A PHYSICAL TRAINING CENTER

Approved:

Date approved by Chairman May 13, 1946

ACKNOWLEDGMENT

I wish to express my thanks to the Architects, Bush Brown and Gailey and associates, for the use of a preliminary set of plans.

TABLE OF CONTENTS

DEFINITION OF SYMBOLS USED

H.F. Foot-candles, intensity on horizontal plane.

V.F. Foot-candles, intensity on vertical plane.

h. Height of the luminaire above horizontal plane.

a. Angle between a vertical line through the light source center and a line through the light source center to the point of unknown intensity.

D. Depreciation factor.

F.C. Foot-candles at a level 32 inches above the floor.

L. Lamp lumens per outlet.

CU. Coefficient of utilization.

MF. Maintenance factor.

A. Area, square feet per outlet.

I. Current, in amperes.

P. Power, in watts.

E. Voltage, wire to wire (line to line).

cos B. Power factor.

C.M. Circular mills, cross sectional area.

P'. Resistivity of pure annealed copper at 25 degrees centigrade.

L'. Length of feeder, in feet.

V. Feeder voltage drop per phase.

ELECTRICAL PLANS AND SPECIFICATIONS FOR A PHYSICAL TRAINING CENTER

GENERAL DISCUSSION OF DRAWINGS AND SPECIFICATIONS

The writing of electrical specifications and the drawing of plans for a large building entail many complex problems. Some of these problems concern the cost, life of the structure, growth and changes in the use, air-conditioning installation, illumination intensities, voltage, power requirements, safety requirements, and emergency service supply. To help in solving these problems the architect usually furnishes the electrical engineer with floor plans or section plans at intermediate levels and with definite data concerning the use to which the building is to be put. Such data include requirements for air conditioning and for the space allotted to service rooms, transformer vaults, and switching areas. As the design progresses, the engineer usually has conferences with the architect and other interested persons about problems of space, position of equipment, and the like.

In addition to this information from the architect, the electrical engineer must know the kinds of service the local utility company has to offer at the selected site, where and how the utility company proposes to make the service connection, and the local as well as the national code requirements for the given kind of building. The utility company will designate the type of service and point of entry when presented with an estimate of the electrical power requirements. The local code regulations can be obtained from the city electrician or county electrician. These regulations supplement the National Electric Code, and certain clauses are more rigid - for instance, those clauses pertaining to permissible fuse sizes, paralleling service entrances, number of entrances, and minimum wire sizes for branch circuits.

With the foregoing information in mind the engineer can now consider the over-all design of the electrical installation. Such clauses of the local code take precedence over the National Code.

He will simplify his problem by starting with calculations for illumination and by establishing all outlet positions and determining the wattage at each outlet. The next step is to determine the locations of larger apparatus, such as air-conditioning equipment, elevator motors, and special power outlets. The approximate positions for the load centers may then be easily determined. This information, together with the knowledge of the use of various floor areas, helps to establish the location of the branch-circuit panels. Each lighting-circuit panel should be so selected that from 10 to 30 per cent of the circuit positions are spares. The percentage, which depends on the kind of building and the use thereof, should be determined and adhered to throughout the design.

The information above is the basis for the calculation of the sizes of the branch-circuit panel feeders and for the selection of the feeder-switching and fusing accessories. The calculations of the feeder sizes present the engineer with the problem of diversity. The size of the feeders and the service entrance should be calculated by the use of a load factor which conforms with the governing electric code.

The kinds of raceways, ducts, and conduit types to be used are determined by the way the building is classified in the electric codes as well as by the engineer's knowledge of the contemplated use of the building and its estimated life.

Generally, the electrical plans may be considered to be complete when they show the location of power and lighting panels, transformer vaults, service rooms, power and lighting outlets, branch circuits and convenience outlets, though they usually also show riser positions and feeder routes. Often, the plans are not drawn in absolute detail, and such items as the number and location of pull boxes are left to the discretion of the contractor, who is bound by the inspecting authorities and the written specifications.

Until recently the general practice in writing electrical specifications has been to include the description and ratings of the apparatus to be installed. But, since illumination engineering has been recognized as a specialized field of electrical engineering, the specifications for lighting equipment are becoming more detailed. These specifications often include a general description of the equipment, as well as the manufacturer's name and catalogue number followed by the words "or the equivalent". This "or the equivalent" implies that if equipment other than that specified is used, it must meet the same tests - namely, photometric, electrical, mechanical, and appearance tests. It is not practical to specify lighting equipment in a general way, such as giving the absolute dimensions, the efficiency, the zonal lumen content, and the brightnesses, unless one or more pieces of equipment meeting the specifications are named.

In specifications for very large installations it is customary to include the luminaire drawings which show dimensions with allowable tolerances, describe the finishes, and give other information regarding each unit. It is not uncommon to attach to the specification manufacturers' drawings and pictures of specified equipment. If the luminaire to be used is unusual in design, it is probable that it is manufactured by only one firm, and if so, the name of the manufacturer and the catalogue number should be given.

DISCUSSION OF THE SPECIFIC PROBLEM

The electrical drawings and specifications for the proposed Indoor Sports Building of the Georgia School of Technology have been selected as a project for this thesis. The building is of unusual design as the roof structure is supported by enormous concrete arches. At the second-floor level a practice track, which extends on cantilever-beam construction, completely encircles the building. The interior has a high, vaulted ceiling, large entrances at each end, and a system of ramps to the higher seat levels.

The following data will be helpful in visualizing the vastness of the proposed structure:

Maximum exterior dimensions -- 360 feet long by 272 feet wide

Arena floor to center ceiling height -- 98 feet

Arena floor -- 200 feet long by 184 feet wide

Floor entrances -- 52 feet wide

Back row of seats -- 52 feet above arena floor

Seating capacity -- 7000

Behind and below the sloping seat areas are offices, classrooms, locker and shower rooms, storage and equipment rooms, corridors, and concession spaces.

Four air-moving equipment rooms are located at the third level, and large ducts for heating and ventilation are built into the structure as an integral part thereof. The control room for public address equipment and the centralized lighting control desk are also placed at this level. A large window placed in this room enables the operators to see the complete arena.

In the planning of the illumination of this building, the arena and seating areas presented a problem for several reasons. One was that the ceiling is high and has a shape similar to the interior walls of a half-cylinder. Furthermore, since it has been the general practice, and is desirable, to have higher intensities on the arena floor area than on the seating area, equipment with definite control characteristics was necessary. This was one factor which eliminated the desirability of fluorescent lighting in this area. Another factor was that preliminary calculations had shown that more than 500 luminaires would be required for sufficient light, and it was believed that regardless of arrangement, the multiplicity of luminaires would detract from the beauty of the structure. Also, from an economic standpoint other systems seemed more desirable.

Indirect lighting likewise seemed out of the question. For one thing, as in the case of fluorescent lighting, such a system does not permit the necessary light control, because of the diffusion brought about by reflection from the ceiling. Then again, the costs involved, costs both in energy and for maintenance, are usually greater for indirect systems. This was especially true of the arena in the Physical Training Center because of the abnormally high ceiling.

An investigation of mercury vapor lamps as a possible source of light for this interior revealed two general disadvantages:

1. They give nearly monochromatic light, which causes many materials, colors and jewels to appear drab and lifeless.
2. They require auxiliary transformers, which present problems of installation and maintenance greater than those of an

incandescent system.

Aside from these two general disadvantages, each of the two mercury-vapor-lamp systems had specific disadvantages which made their use undesirable. The tubular shape of the 3000-watt lamp prevented the use of the kind of reflectors to give the necessary projection and direction control. The 400-watt lamp permits the use of more satisfactory reflectors and therefore has better control characteristics, but it was particularly undesirable in this interior, since it requires an approximate 15-minute cooling period before it will relight. This requirement would have eliminated the ON-OFF control desirable during athletic exhibitions.

Though the three foregoing methods of lighting the building were not desirable, two systems were apparently satisfactory: incandescent floodlighting and incandescent high-bay lighting.

Of the two, the high-bay system was selected solely on the basis of appearance, all other considerations having been approximately equal. The superior appearance of the high-bay system is a result of the fact that these units may be centered in the catwalk floors (both systems require catwalks) and may be effectively louvered.

The selection of the general type of luminaire left the question of desired intensity to be settled. Studies have been made to determine the light necessary to perform various visual tasks, and many of these studies indicate the need for even higher intensity levels than are economically feasible today. It is interesting to note that a well-known electrical handbook published in the yeat 1910 places the level of one foot-candle as being sufficient for reading newsprint. According to present standards, an intensity of more than 25 foot-candles is recommended for this task. Design information is now available which enables the engineer to select the intensity appropriate to modern conception of illumination standards. Tables of recommended intensities for various interiors give the intensity values 32 inches above floor level, and are satisfactory for an engineer to use for most installations. These tables, however, will not solve all problems. The engineer must not overlook an investigation of the flux through the vertical and oblique planes when designing more complex installations. Many commercial and industrial interiors are more usefully illuminated when the light is diffused and when they have at least 50 per cent as much light on the vertical as on the horizontal. Of course, good secondary sources help furnish flux through planes other than the horizontal. The arena floor was the chief secondary source in the Physical Training Center.

An average intensity of approximately 20 foot-candles for athletic practice games seemed satisfactory from a study of recommended intensities and of past experiences. An intensity of approximately 35 foot-candles for exhibition games likewise appeared sufficient.

The foregoing conclusions having been arrived at, it became necessary to consider the mechanics of the installation of luminaires. The following considerations were kept in mind.

The point-by-point method of lighting calculations is the most accurate when high-bay equipment is used. The equations which are given in illumination data books are

$$\text{H. F.} = \frac{\text{Candlepower at Angle a}}{h^2} \times \cos^3 a \times D$$

and

$$V.\ F. = \frac{\text{Candlepower at Angle a}}{h^2} \times \sin a \cos^2 a \times D$$

where

$$D = \frac{\text{Lamp lumens at 70 per cent rated life}}{\text{Initial lamp lumens}} \times \text{Dust Factor}$$

Normal dust factors range from 0.6 to unity, and depend on the location and the use of the building. Lighting-data books give tables for estimating the dust factor. The foregoing equations for intensity presume the lamp to be operated at its rated voltage. Such is rarely the case, so the average lamp voltage should be ascertained from the known voltage drop and the voltage at the service entrance. The equations may be corrected to the actual operating voltage by reference to various lamp data supplied by the manufacturers. A common method of correction utilizes a multiplying factor taken from a curve of initial lumens vs. per cent rated voltage.

In addition to such considerations, the fact that glare at angles less than 30 degrees with the line of sight is harmful to vision was kept in mind in the selection of the mounting height.

In conformance with the information outlined, 84 high-bay reflectors, mounted in three catwalks 75 feet above the arena floor, were specified. These high-bay units would accommodate either the 750-watt or the 1000-watt P.S. 52 incandescent lamp. The wiring was designed so that either wattage could be used.

The wiring was so arranged that alternate lamps could be burned, that the central section of the arena could be lighted alone -- e.g., for exhibition basketball -- or that a few units could be turned on at random. Intensities could be controlled from a spotty four-or-five average foot-candles to a relatively uniform average of 35 foot-candles. These units were to be switched by magnetic contactors actuated by small push buttons in the control console. Remote control simplified the wiring by keeping the branch circuits as short as possible. It also provided ease in control as well as instantaneous control.

Illumination for the seating areas outside the vaulted part of the structure was provided by built-in, flush-mounted units with prismatic glass lenses. The illumination equipment recommended for the upper corridors also included these units. Three 1000-watt floodlights were used in each outside catwalk to provide light for seating purposes only.

The press areas, which are on the same level as the track, had their illumination supplied by well-designed fluorescent units. Inasmuch as the track is an integral part of the press areas, it was decided to illuminate the track with similar units. Provision for switching all of the units in the foregoing areas was made in the control room equipment.

With the lighting problem of the main auditorium solved, such other areas as corridors, boxing and wrestling rooms, locker rooms and exterior areas had to be considered. Since fluorescent luminaires present a pleasing atmosphere in large corridors, and the maintenance does not present a difficult problem with ceilings of medium height, the plans and specifications called for such lighting in the entrance corridors. Flush-mounted, prismatic glass lens units were selected for secondary corridors open to the general public. Since concession areas needed an intensity higher than the average corridor intensities, recessed, louvered, fluorescent units were selected for ample illumination and for their adaptability in these areas.

Sufficient intensities in the boxing and wrestling practice rooms were provided by incandescent reflector equipment. These rooms presented an unusual problem in luminaire mounting because of the sloping ceilings. It was decided to mount each luminaire approximately 10 inches from the outlet box on a self-aligning suspension fitting.

The lighting for the locker rooms was similar to that for the boxing and wrestling rooms. Incandescent reflector equipment of lower wattage than that used in the wrestling rooms was found to give adequate intensities here. It was necessary to give careful thought to the traffic in these areas in order to have the switches arranged as conveniently as possible, though safety had to be considered. For instance, the switches could not be placed in the wet corridor.

Since office space should have light of good quality and of reasonably high intensity, fluorescent luminaires were selected to be used in these rooms for their functional and their aesthetic qualities.

The illumination for all interior areas other than the arena was designed in accordance with standard procedure, the equation

$$\text{F. C.} = \frac{L \times CU \times MF}{A}$$

having been used. This equation, and the necessary tables for its use, may be found in any modern illumination design handbook.

Though completion of the interior lighting plan was of greater importance, the method of illuminating the exterior required careful consideration. In general, built-in, flush mounted, prismatic reflector equipment was selected for use above the doorways and the exterior ramps, and floodlights for use on the vertical surfaces of the main structure. The floodlighting design, the most important consideration, was carried out according to standard practice, the following equation, which may be found in any design data book, having been used:

$$\text{Number of projectors} = \frac{(\text{Area in sq.ft.})\ (\text{Foot-candles})}{17 \times \text{Beam lumens}} .$$

It was borne in mind that it is poor practice to light large blank areas to the same intensity throughout, because the lack of contrast causes a dreary appearance regardless of the intensity, and that with expanses unbroken by architectural detail, more pleasing results are obtained by allowing the intensities to vary over wide limits. These principles together with a study of recommended intensities and a knowledge of floodlighting gained from personal experience led to a choice of a maximum intensity of 12 foot-candles. The architects' models were studied to determine which areas should be brightest and to decide what shading would give a pleasing effect and accent the structural design. These studies indicated the need for higher intensities at the top and upper central regions and along the sides, with shading to lower intensities in central and lower regions. The projectors and bank locations were selected to accomplish the described distribution.

With all interior and exterior lighting and power outlets located, it became necessary to consider the energy distribution system. The first consideration was the feeders. The feeders to the lighting panels were made 4-wire, and those to power panels were made 3-wire in order to have balanced operation in either case. It was kept in mind that a feeder voltage drop of more than one per cent from service room to panel board is not allowed by the National Electric Code and that with power feeders to motor panels additional clauses in the Code limit the wire sizes. The feeder currents were calculated by use of the equation

$$I = \frac{P}{\sqrt{3}\ E\ \text{Cos}\ B} .$$

After the route of the feeder was decided upon and the length scaled, the wire size was calculated, the value of current as determined by the above-mentioned formula having been used. A specially designed slide rule helped to make these calculations by saving time and eliminating the possibility of errors which often occur from the use of more laborious methods. The slide rule was checked for balanced 3-phase calculations by the equation

$$CM = \frac{P'\ L'\ I}{.98\ V} .$$

The final step in the whole distribution problem was the selection of raceways. The conduit sizes were taken from tables published in the 1940 issue of the National Electric Code. Auxiliary guttering was designed in accordance with Article 274 of the same issue. With these selections made, the solution of all electrical problems was completed, and the remaining task was to write the specifications below.

S P E C I F I C A T I O N S

FOR

ELECTRICAL WORK

FOR THE

CONSTRUCTION OF THE GEORGIA SCHOOL OF TECHNOLOGY

PHYSICAL TRAINING CENTER

ARCHITECTS

BUSH BROWN AND GAILEY

ASSOCIATES

HEFFERNAN AND AECK

ELECTRICAL ENGINEER

HOWARD L. MCKINLEY

ARTICLE 1: GENERAL CONDITIONS

The Contractor shall carefully refer to and read the general conditions and special conditions which are a part of the following specifications.

ARTICLE 2: SCOPE

The Contractor shall furnish all labor, materials, and apparatus necessary for the installation of electric light and power wiring and shall furnish all equipment for lighting. Installation of equipment and materials as specified herein and/or called for on the drawings shall be completed. The completed installation shall comply in every respect with the National Electric Code and any County or Municipal Code requirements which exist in the County of Fulton and the City of Atlanta.

ARTICLE 3: WIRING PLANS

The wiring plans are attached hereto, and have the names Bush Brown and Gailey, Architects, Atlanta, Georgia, and Howard L. McKinley, Electrical Engineer, Atlanta, Georgia, affixed. The plans are dated October 12, 1945, and are numbered E-1 through E-6.

The wiring plans show continuity by actual line connection or by a system of letters. The drawings should not be scaled for actual outlet location. The Contractor shall refer to building plans and details for dimensions and locations. Any relocation of outlets necessary according to the building plans shall be corrected by the Contractor at his expense.

The Contractor shall refer to the architectural plans and structural drawings of the interior, exterior, sections and details, to familiarize himself with all parts of the work.

ARTICLE 4: SHOP DRAWINGS

The Contractor shall furnish for approval six copies of shop drawings where called for herein, or at the Architects' or Engineer's request.

ARTICLE 5: WORK NOT INCLUDED IN THESE SPECIFICATIONS

1. All telephone or telegraph wiring and conduit.
2. All motor equipment.
3. High voltage cable into the transformer vault.

ARTICLE 6: DEVIATIONS

No deviations from these specifications or the plans shall be made by the Contractor without the written consent of the Architects and the Engineer. Proposals for deviations shall be made in writing, and shall include the reasons as well as an itemized statement of change in cost. When, in the Contractor's judgment, some item should be changed in order to facilitate the carrying forward of the project, he shall report it immediately to the Architects and the Engineer.

ARTICLE 7: OMISSIONS

The specifications and the drawings shall be considered part of the contract. Any work covered by one and not the other, shall be completed. The plans and specifications, either or both, shall be considered binding.

ARTICLE 8: CO-OPERATION

The Contractor shall schedule his work, and co-operate with the contractors of all other trades to avoid delay and unnecessary work. He shall notify the other contractors of all openings, etc., in order that provisions may be made for his work.

The Contractor shall do any necessary cutting for the installation of his work, but he shall not cut the work of other trades without the Architects' permission. He shall repair any damage by his workmen, employing the workmen of the contractor whose work was damaged.

No allowance will be made because of an error on the part of the Contractor.

ARTICLE 9: INSPECTIONS, MATERIALS, WORKMANSHIP AND TESTS

The Contractor shall obtain all inspections and permits and deliver them to the Architects, free of charge, before acceptance of the work by the Architects and the Engineer.

All material shall bear the label of the National Board of Fire Underwriters and shall meet the tests of the National Electrical Manufacturers Association.

The work at all times shall be under the supervision of a competent mechanic. All work shall be left in the best condition.

On completion of the work a thorough test shall be made in the presence of the Architects and the Engineer. All grounds or short circuits must be cleared, and the resistances between wire and ground, and wire and wire shall be equal or higher than those given in the National Electric Code.

The Contractor shall furnish all materials and instruments for this test.

ARTICLE 10: GUARANTEE

The Contractor shall guarantee his materials and workmanship and shall correct any defects that occur as a result of defective materials or workmanship within one year from the date of acceptance.

Within a period of 30 days after the contract has been awarded, the Contractor shall submit a complete list of all material that he proposes to use. The manufacturer's name, type and catalogue number shall be included. The Architects shall have authority to reject any material not conforming with the specifications. It is further understood that the Architects shall have the authority to reject any part of the work not meeting these specifications. Any work rejected shall be re-finished, and any material rejected shall be replaced at the Contractor's expense.

ARTICLE 11: SYSTEMS OF DISTRIBUTION

The system of distribution for lighting shall be 3-phase, 4-wire, 120-208 volts, 60 cycles per second.

The system of distribution for power shall be 3-phase, 3-wire, 208 volts, 60 cycles per second.

ARTICLE 12: WORK AND MATERIAL IN TRANSFORMER VAULT

The Contractor shall furnish and install in the transformer vault, provided by others, four 125-K.V.A., 70 degree C. rise, 2400/4160-volt Y high-tension and 120 volt low-tension transformers. Each shall be equipped with four $2\frac{1}{2}$%-full-capacity taps below normal in high tension. Transformers shall be complete with non-flammable oil, oil gauge, dial thermometer, provisions for filter-press connections, lifting hooks, and pocket bushings in low tension.

The transformers shall be of the outdoor distribution type, General Electric, Westinghouse, Maloney, or equal.

The primary side of the transformer bank shall be connected in closed delta. The secondary side of the transformer bank shall be connected in wye.

The Contractor shall furnish and install, on the upper wall of the transformer vault for the in-coming 2300-volt primary circuit, three fusible disconnects of 100-ampere rating, General Electric G-101-07-963 F. D. or equal.

The 2300-volt mains shall be brought to the vault by others, but the Contractor shall connect these mains through the fusible disconnecting switches to the transformers.

The Contractor shall furnish and install a secondary bus of four $\frac{1}{4}$-by-4-inch copper bars extending the length of the vault and into the service room to the main service switch. They shall be five inches apart and supported from the ceiling on General Electric insulators #6009927 G. I. or equal. All connections shall be made to the bus with General Electric Tee Clamp #6026205 C - 105 or equal.

ARTICLE 13: SWITCHBOARD

The Contractor shall furnish and install a 3-pole single-throw, 1000-ampere, 250-volt, manually operated air circuit breaker. This circuit breaker shall be at the termination of the bus from the transformer vault and shall be an integral part of the switchboard. The complete switchboard shall be of dead front type, closed at the ends with exposed bus bars on the rear. The switchboard shall consist of an assembly of unit sections. The framework of each section shall be built of 2-inch standard angles welded together to form a free standing, rigid assembly. A pull box shall be installed at the top, extending the complete length of the switchboard. The pull box shall be 10-

gauge furniture steel with a removable back of 10-gauge furniture steel and shall be at least 12 by 12 inches in cross section.

The neutral bus bar shall be bonded to the metal framework of the switchboard and shall also be grounded to the nearest water piping or to a low-resistance driven ground. All metal parts of the switchboard other than current-carrying conductors shall be grounded.

All unit assembly switches shall be fusible, with the fuse links in the dead circuit when the switch is in the open position.

The bus bars and all current-carrying portions of the switching assembly shall be of copper having a conductivity of at least 98% and shall be designed for a current density not to exceed 1000 amperes per square inch of cross-sectional area.

The interior and exterior of the switchboard assembly shall be given a prime coat of rust-resisting paint, and the exterior a finish coat of dead black. The switchboard shall be Trumbell, type RBI or equal. The following switches shall be included:

The main service entrance breaker, specified above.

Three 3-pole, 4-wire, solid-neutral, 150-ampere, 250-volt (switching mains to catwalks A, B, and C)

One 3-pole, 4-wire, solid-neutral, 100-ampere, 250-volt (switching main to exterior floodlights)

Seven 3-pole, 4-wire, solid-neutral, 50-ampere, 250-volt (switching mains to panels 1, 2, 3, 5, 6, 7, and 8)

One 3-pole, 4-wire, solid-neutral 100-ampere, 250-volt (switching main to panel 4)

One 3-pole, 4-wire, solid-neutral, 60-ampere, 250-volt (switching main to panel D third floor level)

Four 3-pole, 3-wire, 100-ampere, 208-volt (switching power mains to each of the four air moving rooms)

ARTICLE 14: EMERGENCY SERVICE

The Contractor shall furnish and install a separate panel in the service room and shall mount thereon a single-pole, 100-ampere magnetic contactor, normally held open, having two energized circuits from two phases of the 208-volt service, connected on the line side of the service breaker. This contactor shall have 208-volt, continuous-duty operating coils and shall be Cutler-Hammer 9576-A-100 or equal. He shall furnish and install on this same panel a 50-ampere, 120-volt, single-phase watt-hour meter loop.

The Contractor shall connect the 120-volt emergency service (brought to the service room by others). The grounded side shall by-pass the contactor and terminate at the meter loop below.

(Note: The emergency system shall be installed in accordance with Article 700 of the National Electric Code, and as shown on the drawings attached.)

ARTICLE 15: CONDUITS

All conduits shall be of the best quality steel tubing, of standard pipe dimensions, smooth inside and out, and shall be double-dip galvanized or sherardized. Conduits shall be General Electric White, Sherarduct, or equal.

All threaded joints shall have red lead applied to the male thread only and shall be water tight. Conduits stored on the job shall be protected from the weather.

Conduits shall be continuous from outlet to outlet and from outlet to cabinet, junction box, or pull box. Conduits shall enter all boxes and be secured in such a way that the conduit will be electrically continuous from any outlet box back to the service room.

All conduits shall terminate in approved boxes or conduit fittings. All fittings shall be galvanized cast iron of proper type and size for each location. Fittings shall be Crouse Hinds or equal.

No bends shall be made with radii less than six times the diameter of the pipe.

Conduit lines shall not be trapped.

All threads shall be clean cut. No running threads shall be allowed. Conduit ends shall butt in the couplings and shall be reamed. Each run shall be smooth and free of inside burrs or obstructions which could injure insulation.

Conduits shall be concealed in furred ceilings, in walls, in slabs, in columns, and in beams, where the size does not exceed $1\frac{1}{4}$ inches. No conduit shall be placed in, nor cutting be allowed on, the main arched girders. No horizontal runs shall be allowed in walls without the Architects' approval.

The conduit lines shall be as direct as possible. In general, bends shall be made with large radii. No run having more than the equivalent of two 90-degree bends shall be allowed from pull point to pull point.

ARTICLE 16: PULL BOXES

Pull boxes shall be installed in order to shorten runs and shall be installed between the equivalent of two 90-degree bends.

Pull boxes shall be galvanized sheet steel of a thickness conforming with Paragraph 93701, Chapter 9 of the National Electric Code.

Pull boxes shall be rigidly installed.

Pull boxes shall be installed so that the removable cover will be accessible.

Pull boxes shall not be used for joint use, such as for both power circuits and control or signal circuits.

ARTICLE 17: WIRING

All conductors shall be copper of at least 98% conductivity.

All branch-circuit wiring shall be #12 except where larger sizes are shown on the drawings. All conductors larger than #8 B & S shall be stranded.

All mains and feeders shall have type R.P. insulation. All other circuits shall be type R insulation, except shower-room wiring, which shall be type R.W. The code type and manufacturers name must be plainly stamped on the braided surface of all wires used. Wires shall be General Cable Company, General Electric Company, or the equivalent. Every coil of wire shall bear the label of approval of the National Board of Fire Underwriters. Where a lubricant will facilitate pulling of wires and cables, powdered soapstone shall be used.

No wire shall be pulled into a system of conduit which has not been completed.

Conductors shall be continuous from outlet to outlet, and no splices shall be allowed in the conduit.

All of the conductors that comprise a circuit shall be enclosed within one conduit.

All splices shall be made mechanically and electrically solid before soldering. Only resin soldering fluxes shall be used. Soldered joints must be smooth and wrapped with approved tapes so that the insulation at the splice is as good as that of any other equal length of the conductor.

Soldered terminal lugs or clamps of approved construction shall be used at the termination of all conductors larger than #10 B & S.

ARTICLE 18: MAINS AND FEEDERS FOR LIGHTING

All mains and feeders shall be as short as possible and shall conform to the following schedule:

Main or Feeder	Switchboard to	Approx. Length in Feet	Number of Conductors and Wire Size	Conduit Size in Inches
A	Sub. Panel A in Catwalk A	132	4 - #00	$2\frac{1}{2}$
B	Sub. Panel B in Catwalk B	155	4 - #000	$2\frac{1}{2}$
C	Sub. Panel C in Catwalk C	179	4 - #000	$2\frac{1}{2}$
D	Sub. Panel D	60	4 - #4	$1\frac{1}{2}$
1	Branch Panel #1	321	4 - #00	$2\frac{1}{2}$
2	Branch Panel #2	237	4 - #2	$1\frac{1}{2}$
3	Branch Panel #3	122	4 - #4	$1\frac{1}{2}$
4	Branch Panel #4	38	4 - #3	$1\frac{1}{2}$
5	Branch Panel #5	153	4 - #4	$1\frac{1}{2}$
6	Branch Panel #6	233	4 - #3	$1\frac{1}{2}$
7	Branch Panel #7	314	4 - #1	2
8	Branch Panel #8	382	4 - #0	2

Feeder	Sub. Panel D to	Approx. Length in Feet	Number of Conductors and Wire Size	Conduit Size in Inches
9	Branch Panel #9	2	4 - #10	3/4
10	Branch Panel #10	115	4 - #8	1
11	Branch Panel #11	340	4 - #4	$1\frac{1}{2}$
12	Branch Panel #12	104	4 - #10	3/4
13	Branch Panel #13	254	4 - #8	$1\frac{1}{4}$
14	Branch Panel #14	442	4 - #3	$1\frac{1}{2}$

SCHEDULE OF WIRING IN CATWALK "A"

Feeder	Sub. Panel A to	Approx. Length in Feet	Number of Conductors and Wire Size	Conduit Size in Inches
15	Branch Panel #15 through Contactor R-19	176	4 - #6	$1\frac{1}{4}$
16	Branch Panel #16 through Contactor R-20	168	4 - #8	1
17	Branch Panel #17 through Contactor R-21	104	4 - #8	1
18	Branch Panel #18 through Contactor R-22	92	4 - #8	1
19	Branch Panel #19 through Contactor R-23	22	4 - #12	3/4
20	Branch Panel #20 through Contactor R-24	32	4 - #12	3/4

SCHEDULE OF WIRING IN CATWALK "B"

Feeder	Sub. Panel B to	Approx. Length in Feet	Number of Conductors and Wire Size	Conduit Size in Inches
21	Branch Panel #21 through Contactor R-7	176	4 - #6	$1\frac{1}{4}$
22	Branch Panel #22 through Contactor R-8	168	4 - #8	1
23	Branch Panel #23 through Contactor R-9	104	4 - #8	1
24	Branch Panel #24 through Contactor R-10	92	4 - #8	1
25	Branch Panel #25 through Contactor R-11	22	4 - #12	3/4
26	Branch Panel #26 through Contactor R-12	32	4 - #12	3/4

SCHEDULE OF WIRING IN CATWALK "C"

Feeder	Sub. Panel C to	Approx. Length in Feet	Number of Conductors and Wire Size	Conduit Size in Inches
27	Branch Panel #27 through Contactor R-13	176	4 - #6	$1\frac{1}{4}$
28	Branch Panel #28 through Contactor R-14	168	4 - #8	1
29	Branch Panel #29 through Contactor R-15	104	4 - #8	1

Feeder	Sub. Panel C to	Approx. Length in Feet	Number of Conductors and Wire Size	Conduit Size in Inches
30	Branch Panel #30 through Contactor R-16	92	4 - #8	1
31	Branch Panel #31 through Contactor R-17	22	4 - #12	3/4
32	Branch Panel #32 through Contactor R-18	32	4 - #12	3/4

ARTICLE 19: MAINS AND FEEDERS FOR POWER

Main or Feeder	Switchboard to	Approx. Length in Feet	Number of Conductors and Wire Size	Conduit Size in Inches
E	Sub. Panel E, 3rd level, equipment room, S.W. corner	60	3 - #000	2
F	Panel F, 3rd level, equipment room, N.E. corner (beneath floor)	412	3 - #000 Lead-Covered	$2\frac{1}{2}$
G	Panel G, 3rd level, equipment room, S.E. corner	290	3 - #00	2
H	Panel H, 3rd level, equipment room, N.W. corner	208	3 - #00	2

ARTICLE 20: PANEL BOARDS

The Contractor shall furnish and install the following panel boards:

Sub. Panel "A", located in Catwalk "A" at termination of Main "A", shall be a fusible distribution panel board, 3-pole, 4-wire, solid-neutral, with six 30-ampere units and one 150-ampere main unit.

Sub. Panel "B", located in Catwalk "B" shall be the same as Sub. Panel "A".

Sub. Panel "C", located in Catwalk "C" shall be the same as Sub. Panel "A".

Sub. Panel "D", located in the S.W. equipment room, shall be a fusible distribution panel board, 3-pole, 4-wire, solid-neutral with six 15-ampere units, and one 100-ampere main unit.

The panel boards shall be surface-mounted units of the combined switch and fuse type, and shall be Westinghouse, or equal.

Sub. Panels E, F, G, and H will be furnished and installed by others; however, the Contractor shall bring the mains to these panels.

The Contractor shall furnish and install branch-circuit panel boards according to the schedule below. These panel boards shall have 4-wire mains, with a breaker in the main and 2-wire branch circuits with thermal overload protection. These boards shall be Westinghouse according to the specified catalogue numbers or the equivalent thereof:

Branch Panel Number	Number of Circuit Positions with 15-Ampere Breakers	Catalogue Number
1	20	NMM20 - 4AB
2	12	NMM12 - 4AB
3	16	NMM16 - 4AB
4	22	NMM22 - 4AB

Branch Panel Number	Number of Circuit Positions with 15-Ampere Breakers	Catalogue Number
5	14	NMM14 - 4AB
6	12	NMM12 - 4AB
7	10	NMM10 - 4AB
8	16	NMM16 - 4AB
9	8	NMM08 - 4AB
10	6	NMM06 - 4AB
11	6	NMM06 - 4AB
12	8	NMM08 - 4AB
13	6	NMM06 - 4AB
14	6	NMM06 - 4AB

The Contractor shall furnish and install branch-circuit panel boards according to the following schedules. These panel boards shall have 4-wire mains with lugs in the mains and 2-wire branch circuits with thermal-type no-fuse breakers. These panel boards shall be surface-type boards and shall be bolted to the sides of the catwalks terminating the feeders having the same number. The panel boards shall be Westinghouse, according to the specified catalogue number or the equal thereof.

Branch Panel Number	Number of Circuit Positions with 15-Ampere Breakers	Catalogue Number
15	6	NMM06 - 4L
16	6	NMM06 - 4L
17	8	NMM08 - 4L
18	8	NMM08 - 4L
19	6	NMM06 - 4L
20	6	NMM06 - 4L
21	6	NMM06 - 4L
22	6	NMM06 - 4L
23	8	NMM06 - 4L
24	8	NMM08 - 4L
25	6	NMM06 - 4L
26	6	NMM06 - 4L
27	6	NMM06 - 4L
28	6	NMM06 - 4L
29	6	NMM08 - 4L
30	8	NMM08 - 4L

Branch Panel Number	Number of Circuit Positions with 15-Ampere Breakers	Catalogue Number
31	6	NMM06 - 4L
32	6	NMM06 - 4L

ARTICLE 20: LIGHTING CONTROL SYSTEM

The Contractor shall furnish and install in the lighting control room one console-type metal desk with thirty-two 2-element positions. Each position shall have immediately below it for identification purposes a 1-by 2-inch card holder with a glass cover. Each position shall be Cutler-Hammer H2540 or equal and shall have a red button for the ON position and a black button for the OFF position. The Contractor shall furnish shop drawings of this desk assembly.

The Contractor shall furnish and install a $1\frac{1}{4}$-inch conduit with 21 #16 control wires from this control desk to each of the catwalks. Each control cable shall terminate in a suitable branching box mounted on the contactor bank.

The Contractor shall furnish and install a contactor-bank framework of 1-inch angle iron firmly mounted in each of the catwalks and shall furnish shop drawings of the contactor-bank assembly.

The Contractor shall furnish and install contactors according to the listing below. These contactors shall be of an electrically held type and of good mechanical construction. They shall be hum free, and shall have silver contacts. These contactors shall have a no-voltage release mechanism, and shall have provisions for 3-wire control. The contactor magnet coils shall be designed for 120-volt, 60-cycle, alternating-current operation.

CONTACTORS IN CATWALK "A"

Number on Plans	Poles	Size Number	Name and Catalogue Number
R-19	3	2	Cutler-Hammer 9592-H801
R-20	3	1	Cutler-Hammer 9592-H697
R-21	3	2	Cutler-Hammer 9592-H801
R-22	3	2	Cutler-Hammer 9592-H801
R-23	3	1	Cutler-Hammer 9592-H697
R-24	3	2	Cutler-Hammer 9592-H801
R-25	3	1	Cutler-Hammer 9592-H697

CONTACTORS IN CATWALK "B"

R-7	3	2	Cutler-Hammer 9592-H801
R-8	3	1	Cutler-Hammer 9592-H697
R-9	3	2	Cutler-Hammer 9592-H801
R-10	3	2	Cutler-Hammer 9592-H801
R-11	3	1	Cutler-Hammer 9592-H697
R-12	3	2	Cutler-Hammer 9592-H801

CONTACTORS IN CATWALK "C"

R-13	3	2	Cutler-Hammer 9592-H801
R-14	3	1	Cutler-Hammer 9592-H697
R-15	3	2	Cutler-Hammer 9592-H801
R-16	3	2	Cutler-Hammer 9592-H801
R-17	3	1	Cutler-Hammer 9592-H697
R-18	3	2	Cutler-Hammer 9592-H801
R-27	3	1	Cutler-Hammer 9592-H697

All of the foregoing contactors shall have NEMA, Type-1 enclosures.

The Contractor shall furnish and install six contactors, eight feet above the floor, one immediately above each of the following panels: 9, 10, 11, 12, 13, and 14. These contactors shall have three poles and be of the same general construction as those specified for the catwalks. The contactors shall have 2-wire control from a 120-

volt, 60-cycle source separate from the controlled circuit. The control circuit shall operate contactors in multiple and occupy one position in the control desk. These six contactors shall be Cutler-Hammer 9592-H532 or equal, and shall be mounted in standard NEMA enclosures.

The Contractor shall furnish and install four contactors, two in the southwest equipment room and two in the northeast equipment room according to the drawings. The four 3-wire control circuits shall be terminated in the control desk. These contactors shall be of the same description as those specified for the catwalks and shall be 2-pole Cutler-Hammer 9592-H501 or equal.

The Contractor shall leave all of the control equipment specified in this Article in perfect operating condition.

ARTICLE 21: FUSES

Fuses shall be installed in all cutouts and a complete duplicate set of fuses shall be furnished.

All switchboard fuses shall be cartridge type, non-indicating, and non-renewable. Fuses other than those in the switchboard shall be cartridge type, renewable.

Fuses shall bear the label of the Underwriters' Laboratories and conform with the dimensions given in Table 34 of the National Electrical Code.

Fuses shall be Westinghouse, General Electric, Buss, or equal.

Fuses shall have such a time-lag characteristic that they will not blow on momentary overload. The blowing time on 150% overload shall not be less than that given in the table below nor more than that allowed in the Standard Specification on Fuses.

Rating in Amperes	Time in Seconds
30	5
60	10
100	15
200	20
400	25
600	30

Fuses shall be of such construction that renewable links can be installed without the use of tools.

ARTICLE 22: LIGHTING OUTLETS

Outlet boxes shall be pressed sheet steel and Sherardized. Boxes shall not be less than 4-inches in diameter nor less than $1\frac{1}{2}$-inches deep.

Fixture studs shall be bolted with 4 bolts, or there shall be an approved locking type of stud mounting. Conduit fittings may be used where outlets occur away from supporting surfaces.

Outlet boxes in furred ceilings shall be rigidly connected to structural members in the ceiling.

Boxes for switches and convenience outlets shall be mounted flush with the finished surface.

ARTICLE 23: SWITCHES AND RECEPTACLES

Switches shall be single pole connected in the hot wires only. Where more than one switch has the same location, they shall be mounted under a common plate.

Switch plates shall clear corners and door jams 3-inches or be mounted in the center of the space available.

Switch plates will be brass and of the best grade available.

Switches shall be mounted rigidly in their boxes.

All switches shall be mounted 48 inches above the finished floor level. Toggle levers shall move upward for the ON position. No switch shall be installed with a toggle lever moving in the transverse direction.

Switches shall be Bryant, General Electric, or the equal.

All receptacles shall be duplex, of the best quality, and installed 14 inches above the finished floor level. Receptacle plates shall be brass and shall match the switch plates. Receptacles shall be Bryant, General Electric, or the equal.

ARTICLE 24: LIGHTING FIXTURES

The Contractor shall install lamps which will be furnished by others.

The Contractor shall furnish and install 84 high-bay reflectors in the catwalks as shown on the plans. These reflectors shall fit over the flanges (prepared by others) in the catwalk floors. At least 4 feet of flexible conduit with 2 #14 A.V.A.-type conductors shall connect the circuit outlet boxes to these units.

These units shall consist of a crystal glass prismatic reflector with permanently spun aluminum cover, a tripod reflector holder and a porcelain mogul socket. The reflector shall be supported from below by three 5/16-inch diameter spring steel prongs held 120 degrees apart by a steel retaining ring. The prongs shall terminate in a movable collar which allows adjustment for focusing. The mogul socket shall have a nickel-plated screw shell and center contact. The stem shall terminate in a 3/4-inch female pipe thread. The diameter of the reflector shall be not less than 19-3/4 inches and the over-all length of the unit not greater than 27 inches. The socket shall be so located that no less than 43% of the bare lamp lumens shall be emitted in the 0-30 degree zone, and not less than 72% in the 0-60 degree zone. The unit shall hold the 750-watt or the 1000-watt standard incandescent lamp.

These high-bay units shall be Holophane 691-AL or equal.

The Contractor shall furnish and install, according to the seating-light locations on the plans, six 1000-watt floodlights. These projectors shall be Alzak coated aluminum and shall have a beam spread of more than 75 degrees but less than 105 degrees. Units shall have 4-bolt, swivel mounting-brackets and shall be mounted on the outside catwalk rails.

These floodlights shall be Smith & MacFarland Lamp Company 1002 or equal.

The Contractor shall furnish and install, according to the plans, on the outlets marked with the letter "A", sixty-four 16-inch, standard R.L.M. porcelain-enameled reflectors. These reflectors shall be white inside, green outside, and so made that the reflector and socket assembly may be easily removed. The design shall be such that the lamp lights only when the reflector is perfectly locked to the hood. These units shall be fitted with mogul sockets and shall be mounted on self-aligning conduit extensions 10 inches below the outlet boxes.

These reflectors shall be Westinghouse 1218898, or equal.

The Contractor shall furnish and install, according to the plans on the outlets marked with letter "B", forty-nine 14-inch standard R.L.M. dome reflectors with medium sockets. The specification for the reflector and installation shall be in all other ways the same as that of the letter "A" locations.

These reflectors shall be Westinghouse 1218897, or equal.

The Contractor shall furnish and install according to the plans, on the outlets marked with the letter "C", sixty 14-inch standard R.L.M. dome reflectors with medium sockets. This specification shall be the same as that for outlets marked with the letter "B".

These reflectors shall be Westinghouse 1218897, or equal.

The Contractor shall furnish and install, according to the plans, on the outlets marked with the letter "D", 32 prismatic lens units. These units shall be complete, consisting of an optical train which includes a 12-inch-square, crystal-glass lens of the sectored plano-convex type regressed to a flat plane in steps not less than 8 to the inch. The segments shall be distributed in an equally spaced, concentric form, and shall extend into each corner. The top side of the lens shall be stippled by ellipsoidal projectors to provide diffusion. There shall be a crystal-glass reflector optically designed to co-operate with the lens. These optical elements shall be assembled and housed in a roughing box constructed of #16 gauge steel approximately 13-7/8 inches square by 10 inches deep. These units shall be lamped with standard 150-watt lamps. These units shall be Holophane F-1774, or equal.

The Contractor shall furnish and install, according to the plans, on the outlet positions marked with the letter "E", 24 flush mounted prismatic glass units. Each unit shall consist of four prismatic lenses and reflectors mounted in line. The lenses and reflectors shall have the same characteristics as those specified for the letter "D" locations. The roughing box shall be #16 gauge steel and shall be one continuous piece with concealed hinges. These units shall be lamped with four 150-watt standard incandescent lamps.

These units shall be Holophane F-1739-4 or equal.

The Contractor shall furnish and install, according to the plans, in the fixture positions marked with the letter "F", 24 troffer type fluorescent units. Each unit shall be equipped with socket holders for two 100-watt F. lamps, and shall have ballasts with power factor correcting condensers built therein so that the average power factor shall be not less than 90% lagging. These units shall be equipped with high quality, "no-blink" starters. The troffer reflector shall be of white porcelain enameled steel and shall have slots at one foot intervals for louvers. These fixtures shall be lamped with 100-watt, white, fluorescent lamps.

These units shall be Day-Brite, #52200, with louver #9924, or equal.

The Contractor shall furnish and install, according to the plans, in the positions marked by the letter "G", 20 troffer luminaires, each shall have socket assemblies to accommodate two 48-inch, 40-watt lamps. These units shall have an etched glass cover plate, and shall be equipped with approved power factor correcting ballasts, and shall be equipped with "no-blink" starters. These units shall be lamped with 40-watt, white fluorescent lamps.

These units shall be Day-Brite #42200 CO or equal.

The Contractor shall furnish and install, according to the the plans, in the positions marked by the letter "H", 36 standard, R.L.M. porcelain enameled steel reflectors, 12-inches in diameter, with medium sockets for 100-watt incandescent lamps. Otherwise, this specification shall be the same as that for outlets marked "B".

These reflectors shall be Westinghouse #1218916, or equal.

The Contractor shall furnish and install, according to the plans, at the outlets marked with the letter "I", 10 built-in, fluorescent lamp units. Each shall have provisions for two 40-watt lamps.

These lamps shall be soft white. Otherwise, this specification is the same as that for outlets marked "G".

The Contractor shall furnish and install, on the outlet positions marked by the letter "J", 17 ceiling type, louvered, fluorescent units. These units shall have socket accommodations for four 40-watt, 48-inch fluorescent lamps and shall be equipped with "no-blink" starters. These units shall be Day-Brite #60448, or equal.

The Contractor shall furnish and install, according to the plans, on the outlet marked with the letter "K", 29 louvered, fluorescent luminaires. These units shall be equipped with Alzak aluminum reflectors and etched aluminum louvers. Each shall be lamped with two 40-watt, white, fluorescent lamps.

These units shall be Wakefield Brass Company #10204 "Grenadier", or equal.

The Contractor shall furnish and install, according to the plans, at the outlet locations marked with the letter "L", 52 prismatic lens units of the same optical train and housing as that specified for the positions marked by the letter "E". These units shall be lamped with 200-watt, incandescent lamps.

The above units shall be Holophane #F 1774, or equal.

The Contractor shall furnish and install 144 fluorescent luminaires on the outlets marked with the letter "H". These luminaires shall have provision for two 40-watt fluorescent lamps and power factor correcting ballasts. These units shall have a glossy white, hard, reflecting surface. The reflecting surface shall maintain rather than distort the color quality of the lamp. Each luminaire shall be so shielded that, when viewed from normal angles, the lamp is invisible. These units shall be mounted on the ceiling so that their major axis is parallel to a tangent of the track curvature.

These luminaires shall be Curtis Lighting Inc. "Twin Skylux" #895C, or equal.

The Contractor shall furnish and install thirty-two 1000-watt floodlight projectors on the flat roof sections according to the plans. These projectors shall be of sturdy construction and shall have a weatherproof, dust-tight, housing. An aluminum alloy trunion with both verticle and horizontal adjustment stops, and provisions for mounting on flat surfaces, shall be an integral part of the projector. The lens shall be of clear, heat resisting, Pyrex glass approximately 16 7/8-inches in diameter. A three foot cable shall enter the housing through a watertight stuffing box. Each projector shall be provided with a hand type focusing mechanism which may be operated without opening the lens door.

CONCLUSIONS

In the problem discussed in this paper the illumination of the arena was a major difficulty because of the unusual design of that portion of the sports building. The solution to this problem, though elaborate in some respects, was a practical one. To facilitate maintenance of the lights, large catwalks with side rails were decided upon; and to facilitate switching, contactors, operated from the control-room console, were installed.

The problem in distribution was more complex than that usually encountered, because of the many curved walls, offset floor areas, sloping ceilings, and large ventilation ducts. An apparently satisfactory solution required more thought and planning than that required for an average distribution system.

In some respects the specifications were written in more detail than those for the average project of the same magnitude. The specifications for the lighting equipment were made very concise.

One procedure in making the specifications was completely standard practice: that is, the citation of clauses in the National Code. Clauses in the National Electrical Code were cited throughout the specifications so that the contractors would not be doubtful about the proper performance of certain parts of the installation.

Although the specifications were written in detail, some of the information was not included on the plans. For instance, the plans did not include a riser diagram or a detailed drawing of the catwalk. Furthermore, since the specifications called for shop drawings of the service-room equipment, this information was not given on the plans.

In conclusion, any one who reads this discussion of how the illumination problems of the Indoor Sports Building at the Georgia School of Technology were solved will see how the solutions differ from those of many other installations and will realize that there is always a wide variation in the solutions of problems of large installations. However, the reader can feel sure that the engineering methods used here have been tested in practice and have given satisfactory results.